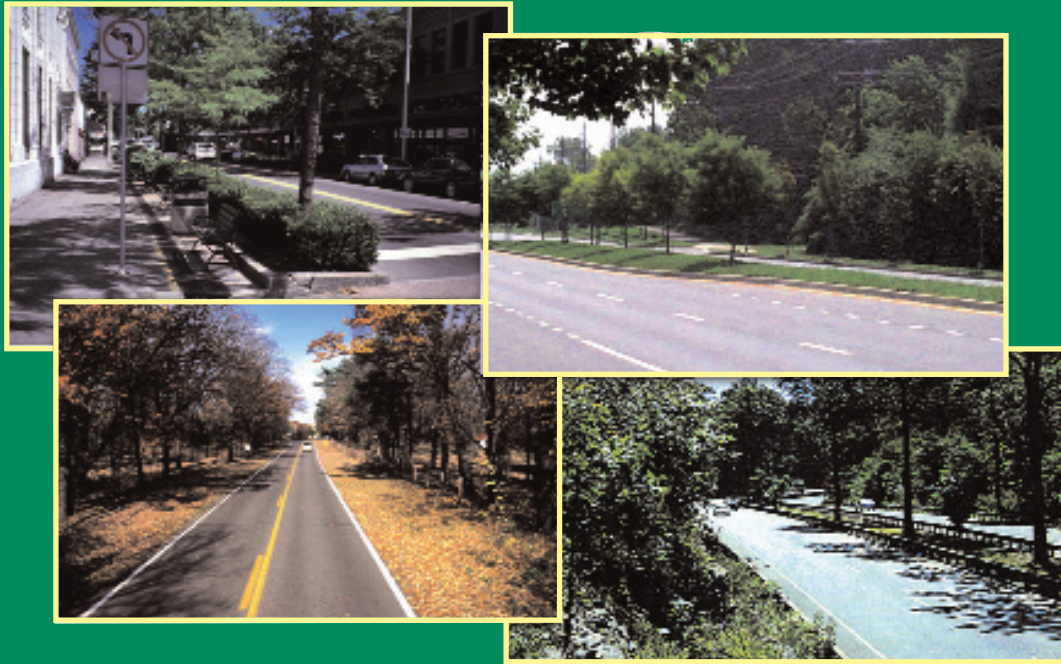




A Guide for Achieving *Flexibility* in Highway Design

May 2004



American Association of State Highway and Transportation Officials

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- Task Force on Environmental Design (Design)
- Task Force on Geometric Design (Design)
- Task Force for Roadside Safety (Design)
- Subcommittee on Legal Affairs (Administration)

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introduction

Context-sensitive solutions (CSS) are an emerging concept in highway project planning, design, construction, and maintenance in recent years. CSS reflects the need to consider highway projects as more than transportation. CSS recognizes that a transportation facility, by the way it is integrated within the community, can have far-reaching impacts (positive and negative) beyond its traffic or transportation function. The term CSS therefore refers to an approach or process as much as it does to an actual design or solution.

The term *Flexibility in Highway Design* was adopted by the Federal Highway Administration (FHWA) in their groundbreaking publication (issued in 1997) that demonstrated how agencies could accomplish the objects of CSS within accepted design processes and criteria. The core theme of the FHWA publication was flexibility—in design approaches, use of criteria, execution of design solutions, and incorporation of special or “unique” features:

This Guide [Flexibility in Highway Design] encourages highway designers to expand their consideration in applying the Green Book criteria. It shows that having a process that is open, includes good public involvement, and fosters creative thinking is an essential part of achieving good design.

The terms *context-sensitive solutions*, *context-sensitive design*, and *flexibility in highway design* are used interchangeably by some. Other terms expressing the concepts include *place-sensitive design* and *Thinking Beyond the Pavement*. These terms all refer to the same process and result: a highway or transportation project that reflects a community consensus regarding purpose and need, with the features of the project developed to produce an overall solution that balances safety, mobility, and preservation of scenic, aesthetic, historic, and environmental resources.

A national conference sponsored by the Maryland State Highway Administration and FHWA in 1998 produced a definition of context-sensitive design that has been adopted by many:

Context sensitive design asks questions first about the need and purpose of the transportation project, and then equally addresses safety, mobility, and the preservation of scenic, aesthetic, historic, environmental, and other community values. Context sensitive design involves a collaborative, interdisciplinary approach in which citizens are part of the design team.

CSS or flexibility in highway design therefore represents a comprehensive process that attempts to bring all stakeholders together in a positive, proactive environment with the objective being the completion of projects that meet transportation needs and are viewed as improvements or enhancements to the community through preservation efforts and sensitivity to local values. CSS recognizes the need to consider that transportation corridors may be jointly used by motorists, pedestrians, cyclists, and public transit vehicles. In addition to the movement of people, CSS also considers the distribution of goods and the provision of essential services.

The values presented in this guide do not imply that the existing streets and highways are unsafe, nor do they mandate the initiation of improvement projects. This guide is not intended to be a detailed design manual that would supersede the need for the application of sound principles by the knowledgeable design professional, nor is it intended to establish guidelines, criteria, or standards for the design of roadways. The use of the terms *guideline* or *criteria* in this document are not to be considered as a substitute or synonym for the word *standard*.

Historic Background on Flexibility in Design

The great interest in achieving flexibility in design is the culmination of many years of increased involvement of the public in transportation projects. Many State Departments of Transportation (DOTs) have experienced projects in which their rigid application of established criteria, practices, or solutions has come into conflict with community values. Some examples of these conflicts include the value of mature trees versus clear zones, lane width and capacity needs versus provision for bicycle lanes, road widening to meet a prescribed level of service. While the issues are many and complex, and tend to vary by location, transportation providers are recognizing these concerns and are now seeking to provide solutions that reflect appropriate sensitivity to community values.

Public policy objectives dealing with resource preservation and community values are highlighted by a range of national and state legislation on environmental and cultural resource protection, beginning with the National Environmental Policy Act of 1969, and continuing with more recent federal legislation such as the Intermodal Surface Transportation Efficiency Act (ISTEA) of 1991, the National Highway System (NHS) Designation Act of 1995, and the Transportation Equity Act for the 21st Century (TEA-21) of 1998. This legislation demonstrates a clear, strengthened federal commitment toward the preservation of historic, scenic, and cultural resources in the development and implementation of transportation projects.

In response to these trends and legislation, a number of national initiatives and publications have encouraged and demonstrated more flexible and creative approaches to highway project development, including the American Association of State Highway and Transportation Officials' (AASHTO's) *Design Flexibility Case Study Report*, 1997; FHWA's *Community Impact Assessment*, 1996; FHWA's *Flexibility in Highway Design*, 1997; and FHWA's *Community Impact Mitigation Case Studies*, 1998.

Flexibility in Highway Design and the Design Profession

Flexibility in highway design has provoked some measure of discomfort and some misunderstandings both inside and outside the highway engineering design profession. Some have interpreted the initiative as advocating an end to the practice of design as it has been done in the past, or the abandonment of proven design criteria, guidelines, or design standards. Others have been concerned with perceptions of adverse outcomes from projects that are *flexibly* designed. Such

concerns tend to focus on compromises in the safety of the solution, or on increased risk to the owning agency associated with potential tort lawsuits.

In the view of AASHTO, established processes and design guidance are not in conflict with the movement. Furthermore, a well-designed, *context-sensitive* design solution need not increase the risk of a tort lawsuit to an agency. AASHTO supports the concepts and principles of flexibility in highway design and feels that all professionals responsible for highway and transportation projects should understand how to accomplish a flexible design solution within current design processes and approaches.

This publication was prepared to add technical background to the knowledge base of highway and traffic engineers, planners, and other technical specialists who contribute to transportation solutions. It strives to emphasize that flexible design does not entail a fundamentally new design process, nor does it suggest new or revised design criteria. Rather, this publication sets out to show designers how to think flexibly, how to recognize the many choices and options they have, and how to arrive at the best solution for the particular context.

Achieving a flexible, context-sensitive design solution requires designers to understand the reasons behind processes, design values, and design procedures. Indeed, successful implementation of context-sensitive solutions will be largely based on the skills and abilities of the professional staff to incorporate context-sensitive design principles in each step of the project development process. This publication, combined with *Flexibility in Highway Design* published by the FHWA, represents a major step toward providing guidance to state DOTs and other agencies charged with transportation project development. However, this guide does not establish a set of best design practices or processes, nor does it mandate the use of flexible design concepts. In addition, the application of the concept of flexible design will vary between States and from project to project.

Organization of the Guide

This guide is intended to promote the incorporation of sensitive community and environmental issues into the design of highway facilities. It is organized to provide an overview and summary of key aspects of the highway project development process from initial planning through completion of construction plans.

Chapter 1 addresses the overall project development process, including the major steps of planning through final design, the background, applicability and use of design criteria, differences among project types, and project design decision making.

Lessons learned from successful context-sensitive projects suggest that the *alternatives development and evaluation stage*, early in project development, is where context sensitivity is achieved. Transportation alternatives must reflect early, continuous, and meaningful input from the public, resource and regulatory agencies, and affected stakeholders. Alternatives must also be developed with full knowledge and understanding of all physical and environmental constraints. They should reflect a creative, appropriate application of geometric design criteria and guidelines. This can

occur only with an understanding of how such criteria have been developed, and how they are supposed to be used.

Chapter 1 emphasizes that the highway design process is flexible. The concept of flexibility may not be well understood by some highway designers; through this document and other related efforts, AASHTO is attempting to educate the design community.

Flexibility occurs with the many choices that a designer has, including selection of a design speed, designation of key design parameters such as the design vehicle, and decisions about the level of service to be provided. A context-sensitive design process provides a means for these choices to be presented to the public and discussed.

Flexibility continues with the application of design criteria to alternatives development. There is significant flexibility in the presentation of geometric design values published in the 2001 update to the AASHTO publication *A Policy on Geometric Design of Highways and Streets* (commonly known as the AASHTO Green Book). Designers, for example, have the ability to select a reasonable design speed from among a range of speeds appropriate for the type and location of the road. Flexibility is also imbedded in the presentation of many design elements in the AASHTO Green Book. A context-sensitive designer will take advantage of this flexibility.

Finally, there are occasions in which even the most creative use of design criteria produces an unacceptable or infeasible solution. The judicious application of *design exceptions* (the incorporation of design values outside the typical ranges to avoid a conflict or constraint) is appropriate in the context-sensitive design environment as long as the safety and legal risks are understood by the designer, are considered acceptable given site-specific conditions, and are documented well.

Chapter 1 closes with a discussion of the decision-making process. All involved with the project development process need to understand the decision process as it applies to each project. Transportation agencies, charged with the design, construction, operation, and maintenance of facilities, are normally the final decision-making authority. With this authority comes a responsibility to act in a manner that is open and honest, and that demonstrates sensitivity to the community.

Chapter 2 outlines the processes, tools, and techniques through which agencies can develop an understanding and incorporate such understanding of community interests in projects. Effective public involvement begins early, is maintained throughout the project, and is meaningful to the evolution of project plans and decisions.

Essential to a successful project is the identification and inclusion of all stakeholders, establishment of purpose and need, completion of early and thorough project scoping, and development and execution of a tailored public involvement program. Public involvement activities must be planned, budgeted, and managed like any other critical technical task. Techniques, guidelines, and references for conducting public involvement programs are contained in Chapter 2. This chapter also discusses the use of technologies such as visualization to promote and enhance public understanding of a project's visual attributes.

Chapter 2 also emphasizes the role that highway design professionals must play in the environmental planning process. A successful project not only meets community interests and goals,

but also addresses regulatory requirements and resource agency concerns. Environmental studies and input occur in concert with, not separate from, highway engineering design. Alternatives development should reflect a complete understanding of environmental issues and should strive to demonstrate tradeoffs and choices that reflect such issues.

Many highway projects result in a series of decisions, commitments, and promises to stakeholders. Effective public involvement does not end with design decision making, but continues through implementation. Planning and design decisions made by project staff need to be communicated to agency management and need to be fully documented to assure compliance with commitments and promises as the project continues into construction. With this authority also comes the responsibility to provide a safe and efficient transportation system.

Chapter 3 is aimed at highway design professionals charged with the development and evaluation of highway alternatives. A common interest of both highway designers and the public is the enhancement of safety in every highway project. This task is sometimes easier said than done in the context of constrained corridors and given other community objectives. It is imperative that highway designers working in the context-sensitive environment demonstrate an understanding of the functional, operational, and safety basis behind their agency's design criteria to enable flexible, creative decisions. Chapter 3 provides an overview of key geometric elements, including a discussion of the models and assumptions used in the derivation of AASHTO design criteria, and a summary of current knowledge regarding operational and safety effects of design. Geometric features that are discussed include horizontal and vertical alignment, cross section, sight distance, intersections and access control, and bridges.

Chapter 3 also addresses in detail two specific concerns that repeatedly occur in context-sensitive projects: roadside design and traffic calming. Resolving potential safety conflicts with trees, decorative walls, and other roadside objects is a frequent problem in reconstruction projects. Designers faced with tradeoffs between maintaining the scenic character of a road and enhancing safety require an understanding of roadside design principles. With respect to traffic calming, the public frequently expresses concern about inappropriate speeds of traffic through towns, business districts, and residential streets. Providing a highway that promotes low-speed operation while meeting safety and mobility objectives is among the most prevalent context-sensitive design issues. Designers need to understand principles of traffic calming, what is effective (and what is not), and how to work with communities to develop effective traffic-calming projects where these are the proper approach to a problem.

Chapter 4 addresses major issues and concerns of agencies and design professionals regarding their responsibilities. Developing a project to meet the context-sensitive environment will take creativity by individuals and agencies charged with assessing design tradeoffs and making project decisions.

Design engineers are concerned with the legal implications of implementing design solutions outside the usual ranges. Many agencies have experienced lawsuits stemming from crashes. There is a widespread concern among design professionals that embracing context-sensitive design will increase an agency's and even an individual's exposure to the risk of being sued should a crash occur.

Design professionals and the public need to understand basic concepts of tort liability and sovereign immunity. Although state laws vary, tort laws generally draw important distinctions between

discretionary and *ministerial* actions. Planning and design decisions that require the assessment of tradeoffs are considered to be discretionary functions, which are generally immune from tort actions. The legal principle is that judges and juries should not substitute their judgment for those of professionals in technical matters. The courts generally provide broad protection for those decisions where it can be shown that reasonable discretion was exercised. Ministerial actions generally involve clearly defined tasks performed with minimal leeway for personal judgment. These are typically implementation actions such as maintenance or construction at the operational level. It is these types of actions for which agencies are held liable if they are not performed adequately. This is not to say that the risk of a lawsuit involving design decisions is negligible. Note that state laws vary, and state court precedents may also vary. All highway designers need to understand the laws and regulations in place for the jurisdictions where they work.

A hindrance in the acceptance of context-sensitive design approaches by some has been a concern about the legal ramifications of design decisions that incorporate nontraditional design solutions. Chapter 4 notes that experience varies across the country. In some jurisdictions, very few successful tort actions involving highway agencies actually result from geometric design issues. In others, tort claims related to design are a continuing concern, and the risk of these claims needs to be understood. In general, it appears that the nature of tort laws and recent history suggests that designing innovative solutions should not necessarily increase the risk to an agency as long as appropriate risk management measures are undertaken.

Chapter 4 summarizes how highway design professionals can successfully accomplish flexibility in design while protecting the public and the legal interests of the owning agency. Transportation design professionals, as individuals as well as representatives of or consultants to agencies, have duties and responsibilities to act in a reasonable manner and to demonstrate adherence to good practice. Among the factors of great importance in the context-sensitive environment is the need to fully evaluate and document all reasonable alternatives. Thus, it would seem that the requirements for a successful context-sensitive project are consistent with good practice to minimize risk: openly developing and evaluating multiple alternatives, assessing tradeoffs among many variables including safety, and documenting all decisions.

The above is not to say that the context-sensitive design environment will be risk-free with respect to tort liability. Again, state laws, precedents, and practices vary. Furthermore, it is an unavoidable fact that DOTs face public and legal scrutiny for virtually all their actions. However, if a design team works closely with stakeholders, is creative within the bounds of good engineering practice, and fully documents all decisions, they will have gone a long way toward minimizing the risk associated with a future tort action should that occur.

As in the AASHTO Green Book, design values in this document are presented in both metric and United States (U.S.) customary units and were developed independently within each system. The relationship between the metric and U.S. customary values is neither an exact (soft) conversion nor a completely rationalized (hard) conversion. The U.S. customary values are those that would have been used had the figures been presented exclusively in U.S. customary units; the metric values are those that would have been used if the figures had been presented exclusively in metric units. Therefore, AASHTO advises the user to work entirely in one system and not attempt to convert directly between the two.

The experiences of states and other agencies that have led the way in context-sensitive design demonstrate many benefits. Incorporating meaningful public involvement; developing multiple,

creative alternatives; and integrating environmental processes produce better context-sensitive solutions. The process, when applied successfully, is efficient in that it minimizes project delays and the need to re-design or re-study the project. In some cases, projects that have stalled or been shelved for long periods of time have been successfully completed through the application of context-sensitive design approaches. For these reasons, AASHTO encourages highway designers, transportation planners, traffic engineers, and others responsible for highway project development to familiarize themselves with the principles and concepts of context-sensitive design as outlined here, in the AASHTO Green Book, and in the Federal Highway Administration publication *Flexibility in Highway Design*.



chapter 1

The Project Development Process

The construction of a highway or street project is the culmination of a design process that is often lengthy, complex, and involves many agencies and individuals. During each stage of the process, important decisions are made that affect subsequent stages and the overall design outcome.

This chapter provides an overview of the entire highway project development process. It includes a discussion of the major stages of a highway project, background on the major inputs to highway design criteria and design, differences in types of projects, and the design decision-making process.

1.1 Overview of the Process

The highway project development process can be characterized as having four distinct stages, as illustrated in Figure 1-1. The four stages—concept definition, planning and alternatives development, preliminary design, and final design—generally apply to all projects from inception through construction and maintenance. Note that, depending on the size and complexity of a project, the overall process can take months to several years.

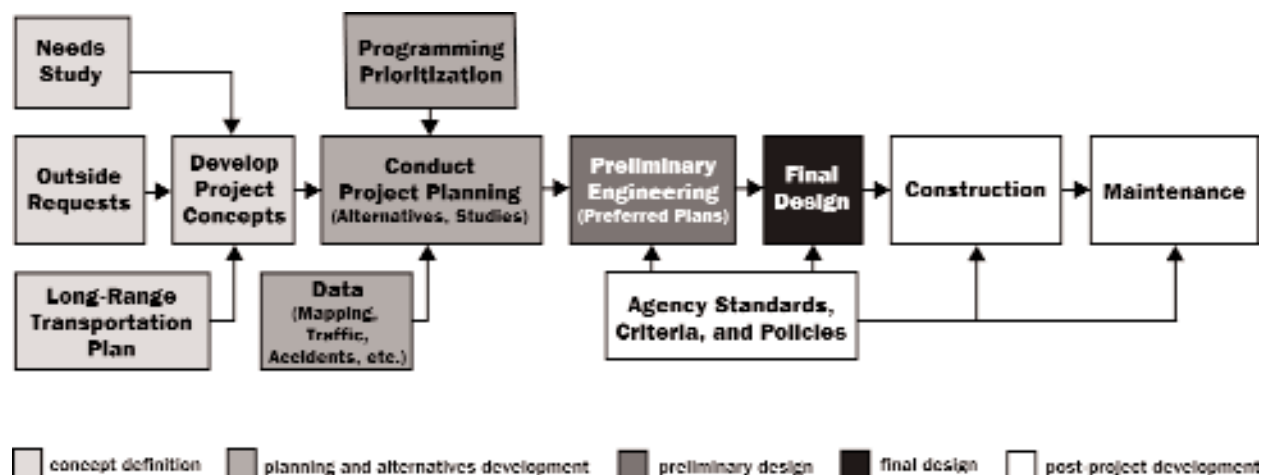


FIGURE 1-1
Typical Project Development Process

Departments of Transportation (DOTs) and other transportation agencies utilize a range of terminology to describe their process. The process outlined in Figure 1-1 and the terminology employed here are generally accepted. For the purposes of discussion, the process and terminology are as follows:

- **Concept Definition**—The identification of a project, including its need, geographic limits, and other specifics to enable studies to begin.
- **Planning and Alternatives Development**—The broad range of activities that result in the selection of a preferred plan that meets regulatory requirements and is sufficiently detailed to proceed with final design and construction.
- **Preliminary Design**—The initial stage of the final design process to confirm right-of-way needs.
- **Final Design**—Completion of design documents and specifications for construction of the project.

1.1.1 Concept Definition

In the *concept definition* stage, the purpose and need for a project or improvement is identified. Such need may come from regular performance monitoring (e.g., pavement condition, congestion, safety history), from a local governmental request made necessary by actions of others (e.g., in response to land use changes or development), by legislative direction, or by response to an emergency. Concept definition involves defining the need and purpose of an improvement, the limits of the project, and often the schedule and funding of the project.

A key to context-sensitive planning and design is developing a clear understanding during concept definition of the need for a project, which involves an understanding of the transportation problem and the context of the project area that requires addressing. In short, the concept definition stage represents an important decision of project stakeholders to take action by committing to solving a problem on a specific route or in a specified area or corridor. The details of the solution(s) are arrived at in subsequent project development stages.

1.1.2 Planning and Alternatives Development

The *planning and alternatives development* stages involve that part of the process in which alternatives are proposed and studied, environmental and community impacts are assessed, and decisions are reached about the key physical, environmental, community need, and operational aspects of the proposed project. *During this stage, the greatest opportunities and challenges for a flexible transportation solution occur.*

Once the purpose and need for a project have been determined with public input, design criteria are selected by the transportation agency and reviewed with the project stakeholders. Note that this occurs early in the overall project development process. The basis for the project design criteria will generally be the transportation agency's design guidelines. Project design criteria should recognize both the functionality of the roadway improvement (its use once it has been improved) and the values of the community.

During the *planning and alternatives development* stages, designers, working with planners, environmental specialists, the public, and agencies, have the greatest latitude to propose, study, and evaluate a full range of alternatives. Clearly, it is during this stage of the project that the designer can have the greatest influence on the quality of the design, which includes not only its traffic-carrying capability and safety performance, but also its effects on the community and surrounding land uses.

The *no-build* or no-action alternative is usually considered during this stage. As the designers and community consider various plans, it is always possible that no acceptable solution will be reached that addresses the purpose and need.

Each *build* alternative proposed for the project must satisfy the purpose and need agreed to by the full range of stakeholders. This understanding should be forged in the earliest stages of the project and modified as needed during project development. Appropriate consideration should be given to the environmental, scenic, aesthetic, historic, cultural, and natural resources of the area in addition to serving the motorists and other users in a safe and efficient manner. Accordingly, special attention should be paid to developing and/or refining design alternatives, transportation solutions, or features that are consistent with local interests and values while still addressing the safety and operational needs of the facility.



FIGURE 1-2
Public Information Meeting
at which Design Alternatives
Are Being Shown and
Discussed

The alternatives development stage normally includes key aspects of geometric design. A feasible alternative is one that meets the project's purpose and need and is considered constructable and maintainable within the social, economic, and environmental constraints of the project area. This determination normally requires that an alternative be developed to sufficient detail to enable reasonable resolution of construction costs, right-of-way requirements, environmental effects, and traffic operational quality. In most cases, the highway designer prepares a "functional" geometric plan for each alternative to enable such analyses. Thus, geometric design plays a substantive role in this early planning stage. (For more detail on geometric design elements, refer to Chapter 3.)

Incorporating public input into the project begins early on during the planning and alternatives development stage (Figure 1-2). Indeed, *context-sensitive* project teams make an effort to fully understand community values *before any concepts or solutions are proposed*. This assures that

the project will be developed to represent the needs of the highway users (both local and through travelers), as well as the community at large. Insights gained from public involvement activities outline the needs and concerns of the community. Understanding and addressing such needs can result in early community buy-in for the project before it has advanced to a stage where further changes cannot realistically be made or the project becomes unacceptable.

Maintaining sufficient contact with the public throughout the alternatives development stage is essential to ensure that all issues surrounding an improvement project are addressed in its design. Some issues may reflect major concerns about the project in general; others may involve details for which little may be known until later in the design. Knowing that all issues have been raised and are being addressed greatly reduces the chance that an unforeseen issue with substantive effects is raised during later preliminary and final design stages. It may also reduce any tension that could arise from participants concerned that their inputs are not being properly considered.

Appropriate and efficient incorporation of public involvement requires careful planning and execution, similar to other elements of project development. A complete discussion of public involvement in the design process is provided in Chapter 2.

Feasible alternatives must also meet environmental regulatory requirements. Thus, close coordination with many resource and regulatory agencies is essential during this stage of work. Also, appropriate analyses to document the effects of proposed alternatives occur during this stage of the project.

The culmination of the planning and alternatives development stage is the selection of a preferred plan or solution by the transportation agency. This is often accompanied by the completion and acceptance of an environmental document and endorsement by local stakeholders.

1.1.3 Preliminary Design

Preliminary design occurs following the acceptance of a preferred plan, only after all alternatives have been considered. In this stage in the process, the geometric elements of the highway or street are developed to sufficient detail to firmly establish their impacts and full right-of-way and construction requirements. The highway designer refers to agency design criteria, with all three-dimensional elements mathematically established. Field survey information is developed to sufficient detail to enable the definition of right-of-way, utility, and other information necessary to construct the project.

During preliminary design, the plan developed in the earlier planning stages is refined and adjusted to reflect greater knowledge learned about the location, including input on utilities, survey ties, specific concerns of property owners, etc. Design plans also evolve based on the consideration of constructability issues and maintenance of traffic during construction.

A project that has been carefully developed during the planning stages should not result in major, substantive changes in the preliminary design stage. Stakeholders, and in particular affected property owners, expect that the elements of the preferred plan described in the planning stage will be carried forward to design and construction.

At some point in the preliminary design process, the designer must prepare documentation of the design and significant design decisions. This may occur or begin at the end of the planning and alternatives development stage. Acceptance of a design value that is outside normal practice or design criteria of the project or agency must be highlighted and discussed in a document, which will support future inquiries of the agency about why the recommended solution was constructed.

The flexibility to address the design of a project in this context currently exists in the American Association of State Highway and Transportation Officials' *A Policy on Geometric Design of Highways and Streets (1)* (commonly known as the AASHTO Green Book) and in many state design manuals or guidelines. The use of ranges in most design criteria and the various functional classifications for a roadway provide design flexibility. Both motorized and non-motorized transportation modes must be considered in this stage.

1.1.4 Final Design and Construction

The *final design* stage of a project results in the production of complete plans, specifications, and construction bid documents of sufficient detail for the agency to contract for the actual construction of the project. Detailed aesthetic treatments are developed during this stage. It is common for some minor revisions to the plan to occur to save costs, improve constructability, and reflect refinements based on actual right-of-way acquisition negotiations and additional survey and mapping information. However, as with the preliminary design stage, the public, stakeholders, and affected property owners expect that the final plans will closely follow plans developed and presented in earlier stages and will follow the spirit of the commitments and decisions made in earlier stages.

It is vitally important that public involvement continue through this stage, as well as the stages that follow. It is common that seemingly minor field revisions be made during construction to design plans. Keeping the public abreast of such changes, and assuring that changes do not conflict with commitments or promises made during earlier project stages is essential. Indeed, for many projects, the most sensitive and potentially damaging stage of the work includes construction, when residents and business owners may be substantially affected by construction activities for many months. The public is interested in the timing of construction, detours, road closures and plans for maintaining traffic, and issues such as construction traffic, noise, dust, and other potential concerns. The public will also be interested in the impact of alternative transportation modes such as pedestrian, bicycling, and transit.

1.2 Philosophy of Geometric Highway Design

Geometric design is defined as the design of the visible dimensions of a highway, with the objective being the *forming* of the facility to meet the functional and operational characteristics of drivers, vehicles, pedestrians, and traffic. This is both a science and an art. Geometric design deals with features of location, alignment, profile, cross section, and intersections for a range of highway types and classifications.

The geometric form and dimensions of the highway should properly reflect driver safety, desires, expectations, comfort, and convenience. It should do so within the context of a host of constraints

and considerations, including terrain, land use features, roadside and community effects, environmental effects, and cost considerations.

Central to the geometric design process is the application of design criteria and guidelines. Such criteria and guidelines provide acceptable dimensions or values for the purpose of producing a facility of a given quality (operational and safety) in a cost-effective manner. Experience has shown that the use of generally accepted practices and concepts and uniform design values can provide a reasonable degree of safety. A uniform approach to design provides a consistent “expectation” for the user (e.g., red light at the top of a signal indication, exit to the right, appropriate operating speed, etc.). This expectation is particularly important for the inexperienced driver, the older driver, the driver unfamiliar with the road or area, the distracted or inattentive driver, or the impaired driver. A uniform design approach also addresses the safety and other needs of pedestrians and bicyclists.

Designers are often required to be creative and sensitive in addressing the many facets of design to fit a particular situation. As designers respond to increasing concerns over community value and social, economic, and environmental constraints, the need for flexibility in the design process becomes more significant. Flexibility is best achieved by experienced design professionals in consideration of all known factors and related tradeoffs. Flexibility should not be viewed as a reduction in geometric criteria. Of course, in the pursuit of flexibility, the expected safety performance of the facility should be consistent with that expected of a design meeting published criteria.

For the above reasons, the final products of a well-executed design process may vary greatly between projects executed by different designers, even within the same agency, despite the fact that precisely the same set of design criteria is used. The difference may be based on differences in emphasis (e.g., producing the *lowest cost design* versus one with a higher degree of operational flexibility), the unique context of each location, the technical knowledge of the designer, and the amount of input from others in shaping the design. Clearly, designing safety and operational efficiency into highways is much more than applying and following conventional criteria.

The remaining parts of this chapter provide an overview of the factors that influence the highway design process and the thinking of designers. These include design controls, speed and design speed, types of projects and how designers should approach them, design constraints, and design decision making.

1.3 Design Criteria and Guidelines

The practice of geometric design is focused on design criteria. Design criteria are a collection of design dimensions, decision rules, and guidelines based upon formal research, past experience, and uniform driver expectation. The use of design criteria as a fundamental part of the practice of highway design is intended to provide consistency in the quality, appearance, and operational performance of the highway system. Such consistency is considered important, given that highway segments are designed and maintained by different agencies and individuals.

Design criteria reflect the collective knowledge from operational experience as well as the application of research. The basic criteria for geometric design of highways and streets are found in the 2001 AASHTO Green Book (1).

The AASHTO Green Book (1) is intended for new construction of permanent roads and structures. Transportation Research Board Special Report 214, *Designing Safer Roads* (3), was developed to serve as a reference for use in the design of resurfacing, restoration, and rehabilitation (3R) projects. In addition, many states have developed their own criteria for 3R projects.

1.3.1 Historical Background

The design concepts and values found in the AASHTO Green Book (1) are based on established practice and research. AASHTO has become the focal point for basic geometric design practice in the United States. A national consensus emerged in the early part of the 20th century regarding the need for consistent highway design practice. As travel increased, the amount of constructed road mileage also increased. Over the years, as vehicles changed and operating speeds increased, motor vehicle crashes emerged as a concern and it became more and more evident that an organized, more rigorous approach to design was needed.

In 1914, the American Association of State Highway Officials (AASHO), as AASHTO was known prior to 1973, was created as an organization for state highway professionals to discuss practices. Since that time, it has served as the sponsor or steward for the evolution of highway design practice. Such design practice has evolved over the past 90 years in response to technological changes, the growth of the nation and economy, and social policy changes. Table 1-1 lists the evolution of AASHTO design guidance from 1938 to the present.

TABLE 1-1

Evolution of AASHTO (AASHO) Design Policies in the United States

<i>A Policy on Highway Classification</i> , September 16, 1938
<i>A Policy on Highway Types (Geometric)</i> , February 13, 1940
<i>A Policy on Sight Distance for Highways</i> , February 17, 1940
<i>A Policy on Criteria for Marking and Signing No-Passing Zones for Two and Three-Lane Roads</i> , February 17, 1940
<i>A Policy on Intersections at Grade</i> , October 7, 1940
<i>A Policy on Rotary Intersections</i> , September 26, 1941
<i>A Policy on Grade Separations for Intersecting Highways</i> , June 19, 1944
<i>A Policy on Design Standards-Interstate, Primary and Secondary Systems</i> , 1945
<i>Policies on Geometric Highway Design</i> , 1950
<i>A Policy on Geometric Design of Rural Highways</i> , 1954
<i>A Policy on Arterial Highways in Urban Areas</i> , 1957
<i>A Policy on Geometric Design of Rural Highways</i> , 1965
<i>A Policy on Design of Urban Highways and Arterial Streets</i> , 1973
<i>A Policy on Geometric Design of Highways and Streets</i> , 1984
<i>A Policy on Geometric Design of Highways and Streets</i> , 1990
<i>A Policy on Geometric Design of Highways and Streets</i> , 1994
<i>A Policy on Geometric Design of Highways and Streets</i> , 2001

Source: *Traffic Engineering Handbook* (2), Table 11-1

The AASHTO Green Book (1) was developed through the cooperative efforts of the AASHTO member departments (including the 50 states, the District of Columbia, and Puerto Rico), the Federal

Highway Administration (FHWA), and numerous research entities, including the Transportation Research Board (TRB), to enhance safety by providing uniform and cost-effective roadway features for motorists. As shown in Table 1-1, beginning with *A Policy on Highway Classification* published in 1938, AASHTO has developed numerous guides covering all aspects of highway design over the 60-plus years since the original policy. It is important to remember that following these guides can be affected by a need to consider alternative transportation modes, or to address environmental quality and social impacts (i.e., community values).

1.3.2 Research Basis

Incorporating ongoing research into highway design solutions is key toward assuring that concerns about safety, design risk, and liability are addressed. AASHTO design guidance is continually refined and revised based on results of research conducted at the state and national level. The National Cooperative Highway Research Program (NCHRP), administered through the TRB, has completed much research that directly addresses geometric design, safety, and traffic operations issues. The FHWA also conducts a substantial research program that contributes to the highway design knowledge base.

Research conducted nationally indicates what is acceptable, how acceptability is determined, and provides insights into the many ways that flexibility can be accomplished through the use of alternate or modified design criteria. Continual research on transportation issues provides additional data that will guide the selection of design criteria for future highway improvement projects and future revisions to the AASHTO Green Book (1).

As research has been completed, lessons have been learned, and changes in the United States vehicle fleet and driver characteristics have occurred, AASHTO has responded by altering appropriate highway design criteria. For example, roadway width criteria, stopping sight distance design values, and roadside design approaches and design values have changed significantly over the years.

The evolution in design criteria continues to present challenges to designers dealing in particular with the reconstruction of existing streets and highways. Many such highways designed years ago met design criteria in place at the time they were built, but no longer meet current state criteria or criteria as published in the AASHTO Green Book (1) for new construction. This challenge is often difficult for the public to understand, particularly when a designer suggests that an improvement may be necessary to address a “non-standard” feature of a highway.

1.3.3 Intended Use of the AASHTO Green Book

Design guidance published in the AASHTO Green Book (1) reflect the consensus of AASHTO’s member departments regarding what constitutes good design practice nationally. In arriving at a consensus, AASHTO recognizes that each region or state has different conditions, constraints, and needs.

The AASHTO Green Book (1) is not intended, and never was intended, to be used solely as a standard upon which to base the design of every highway improvement. Rather, as is noted in the foreword of the Green Book (1), “sufficient flexibility is permitted to encourage independent designs tailored to particular situations.” Such flexibility may be appropriate for a state wishing to use a different basis for design from that indicated in the AASHTO Green Book (1), or for an individual designer working on a range of different projects.

The AASHTO Green Book (1) is clearly acknowledged within the United States highway profession as the definitive collection of geometric design values for highways. The FHWA has adopted the AASHTO Green Book (1) for use as a set of design criteria for new and reconstruction projects on the National Highway System (NHS). The NHS, a 160,000-mi (257,000-km) network of highways designated by Congress in 1995, provides a transportation network for national defense, commerce, intermodal connections, and interstate travel. The NHS includes the 46,000-mi (74,000-km) Interstate System. Although the NHS consists of approximately 4 percent of the nation's roads, it carries 42 percent of the travel.

Many states and localities have also adopted the AASHTO Green Book (1) for use as the basis of their state guidelines with no changes. However, the intent of the AASHTO Green Book (1) is that individual states, cities, and counties have the freedom to develop their own design guidelines and processes based on sound engineering principles that reflect local conditions and needs as well as the needs of the highway users. For such agencies, the design criteria in the AASHTO Green Book (1) can be a starting point or benchmark. Other published design criteria, such as that published by the Institute of Transportation Engineers, may also be referenced by an agency. The AASHTO Green Book (1) is thus a guide, a reference, and a basis for the development of an agency's guidelines. Terrain, climate, culture, values, and driving habits differ across the nation; what is good and acceptable in one location may not be satisfactory or practical in another. For example, AASHTO presents design criteria for horizontal curves with a full range of possible design values for maximum superelevation. The Green Book (1) does not prescribe or even favor one value over another. Rather, States are free to select one or more "maximum superelevation" values based on their climate, design preferences, or other considerations, and to design curves in their state accordingly. Thus, neighboring states may design curves differently from each other, yet both would be following the AASHTO "policy."

1.3.4 Background on Design Criteria

Designers and project stakeholders should understand the origin and nature of design criteria to enable good decisions about applicable project criteria and to assess potential design exceptions. This means understanding the functional basis for each design element, not just what the design values are.

Design criteria by their nature generally reflect a *safety conservative* philosophy within the context of overall cost-effectiveness. Acceptable design values for any feature are established to assure (to the best knowledge available) that the feature itself will not measurably contribute to increased risk of a crash. Thus, for example, design values used for stopping sight distance are generally greater than absolute values required for a driver to avoid a crash. Or, similarly, values for the width of a lane provide additional dimension beyond that necessary to avoid lateral conflicts with other vehicles. (We note here that many design values are established based not only on explicit safety considerations, but also to reflect other needs such as traffic operations, capacity, constructability, maintenance considerations, and other factors. Chapter 3 provides more background.) Such an approach to the development and use of design criteria is consistent with appropriate engineering principles for any significant infrastructure improvement. It is analogous, for example, to the safety factors included in typical structural designs for buildings.

The use of safety conservative criteria is appropriate as a general rule, given the permanent nature of the constructed alignment, and the difficulties and expense of correcting a design problem that results in poor safety performance. Designers must make many assumptions regarding design

traffic and other conditions; their designs will be used by a wide range of vehicle types and driver capabilities; and the highway must perform safely under a range of environmental conditions. The road must also perform adequately for a constantly changing vehicle fleet. The public expects that designers will “get it right” the first time, and that the finished product will meet operational and safety expectations for a long time to come. Thus, the use of conservative design criteria is clearly appropriate as a foundation for highway design.

Designers may on occasion be confronted with a project in which, despite the best efforts to develop a creative design within the agency’s criteria, an acceptable solution cannot be reached. Reaching an acceptable solution may require a designer to use a design value that is marginally outside normal design criteria. Only by understanding the actual functional basis of the criteria and design values can designers and transportation agencies recognize where, to what extent, and under what conditions a design value outside the typical range can be accepted as reasonably safe and appropriate for the site-specific context. This knowledge also allows the design professional to engage the public in an open discussion of what can and cannot be considered acceptable. Recognition can lead to creative yet safe designs when designers must look beyond the criteria due to a constraint or other site-specific problem.

For more insights in this area, refer to Chapter 3 for a discussion of the background behind design criteria for major highway elements.

1.3.5 Design Exceptions—Introduction

One important component of Federal and State regulation is the provision permitting the use of *exceptions* to established design criteria. A *design exception* is a statement of the rationale and need for a specific variance from an established geometric value, criterion, or guideline. The need for such exceptions may arise during the planning and preliminary design process, as alternatives are developed to greater detail and evaluated with input from the public and resource agencies. Put simply, it is sometimes the case that a design which meets full design criteria is unacceptable or unachievable for one or more reasons.

Exceptions to design criteria must be clearly justified by circumstances. Such circumstances should not be solely cost considerations, but should include unusual or significant site-specific constraints (environmental, land use) that preclude the use of normal design values. Design exceptions should be documented by the highway agency and the performance of these atypical designs monitored to assist in future decision making. When considering possible project components that may require design exceptions to the established design criteria, it is important that the resultant safety and risk aspects be 1) understood by the designer, and 2) properly communicated to project stakeholders.

Many designers are reluctant to use design exceptions because of concerns of agency and even personal liability in the future should a crash occur and a tort claim result. In the past 30 years, many state legislatures have given up sovereign immunity, opening agencies to the threat and actual occurrence of tort actions against their staff.

Tort law varies from state to state, and designers need to understand the prevailing laws and court precedents within their state or jurisdiction. The reader is directed to Chapter 4 of this guide for more insights on tort law. With respect to design exceptions, tort risk, and *flexibility* in design, the experiences of many states suggests that sensitivity to tort liability risk should focus as much or

more on the design process and best risk management practices as on the actual design decision. Most State courts will require only that the agency act in a reasonable manner and document the reasons for such action. Where tort suits alleging design defects are successful, often the problem is not necessarily the use of a design value outside the typical range, but the lack of documentation as to what alternatives may have been considered and why the design was adopted. Designers are encouraged to understand the laws of the state in which they practice their profession, and to incorporate full engineering analysis and documentation procedures as part of their design process.

The need for design exceptions is not new and is not inextricably linked to the concept of *design flexibility*. Designers should understand that design exceptions are an acceptable and indeed useful tool *when evaluated and applied properly*. Just as design exceptions should not be sought routinely, acceptance of a design exception should not be viewed as an admission of failure. It does not mean that the design criteria are inappropriate or that a resulting design is automatically less safe substantively than a traditional design. (The reader is referred to Chapter 3, in which technical guidance is presented discussing the relationship between design values and substantive safety risk.) Finally, in discussing design exceptions and criteria with stakeholders, designers should avoid labeling a value that is outside the norm as “unsafe” in the specific circumstances unless he/she has a clear understanding or evidence that this is so.

The resources of a multidisciplinary team including the public can be helpful in determining the context of an improvement project, and perhaps the need for considering design exceptions. Flexible design guidelines ensure that exceptions to established design criteria, when necessary, may be developed with frequent and consistent public involvement and that the transportation agency is responsive to shared community values to the extent possible. An advisory team made up of transportation officials, citizens, local government officials, and other interested individuals can consider the design criteria for a particular project. This advisory team, during consideration of the purpose and need and the established design criteria, can participate in the weighing of impacts of various design elements against community values and the functionality of the improvement.

The professional highway or traffic engineer should provide such a team with the insights and background on the sources of the criteria, latest research on safety effectiveness of the specific design dimensions or features, and a professional recommendation about what can or should not be tried. The advisory team can address appropriate design criteria and the needs of the public, consider alternatives, and make recommendations for consideration by the transportation agency. Of course, the transportation agency, charged with building and maintaining the highway and with the overall responsibility for public safety and expenditure of public funds, is ultimately responsible for the project’s design criteria and actual project design. The transportation agency also has the responsibility to communicate conditions where it has the opportunity to accommodate a community’s shared values in design.

A properly documented design exception process (which includes a crash analysis, benefit-cost analysis, and rationale for deviation from the guidelines), supported with meaningful and timely public involvement, is essential for agencies operating in the context-sensitive design environment. Documentation of design exceptions is among the most important steps to protect a transportation agency against potential tort liability stemming from a crash. Refer to Chapter 4 of this guide for more details on tort liability and design exceptions.

1.4 Highway Design Controls

The highway design process is driven by the establishment of fundamental design controls. These include factors outside the control of the designer (terrain, location, and climate); and other factors including the functional classification of the highway (as defined by its expected use), traffic characteristics (volume, vehicle mix), and speed.

As noted below, many of the fundamental design controls are selected or determined by the design team working with stakeholders and the public. Developing a flexible design begins with appropriate consideration of those controls for which a choice can be made.

1.4.1 Functional Classification

The functional classification and design speed are the primary factors in setting the highway design criteria. The functional classification should be based on the anticipated operation of the highway. Functional classification refers to the types of trips, the mix of drivers, and the role of the highway within the overall highway system. Higher-classification facilities (controlled-access freeways, major arterials) are designed to carry larger volumes of through trips at speeds as high as is practical. Such facilities carry greater numbers of unfamiliar drivers. They also are intended to carry more and larger trucks and commercial vehicles.

Great emphasis should be placed on striving for the highest quality of service for the higher functional class facilities. Creativity is essential in the design of such facilities to provide a context-sensitive design that falls within traditional design criteria. Designers and decision makers should generally be more reluctant to incorporate significant or repeated design compromises for major arterial highways or freeways.

Lower classification facilities such as collectors and local roads serve different functions, including access to adjacent land uses and collection of traffic for access to higher-classification roads. Local roads and collectors may tend to carry somewhat lower traffic volumes over shorter distances at lower speeds. Local roads are driven primarily by familiar drivers making repeated trips. For such facilities, designers can generally be more open to design exceptions to address or accommodate a local constraint.

Note that the *ownership* of a road or street should not be confused with its functional classification. In general, state DOTs will be responsible for the higher-class facilities. However, many local units of government maintain responsibility for arterial highways as well as local streets.

Also, note that a roadway's formal classification as *urban* or *rural* may differ from actual site circumstances or prevailing conditions. An example includes a rural arterial route passing through a small town. The route may not necessarily be classified as urban, but there may be a significant length over which the surrounding land use, prevailing speeds, and transportation functions are more urban or suburban than rural. Designers need to recognize such situations and apply common sense judgments in interpreting design criteria and developing appropriate solutions or design approaches.

Designers, the public, and decision makers must recognize the different highway types in shaping and refining design alternatives. While upgrading the functional classification is often done successfully through reconstruction, reducing the functional classification of a route is much more

difficult. Merely re-designating or re-signing a route does not guarantee that actual traffic patterns and uses will change. Where reclassification of a route is sought, it is often necessary to implement the provision of a suitable alternative route, or discourage traffic through the use of traffic calming or similar techniques.

1.4.2 Terrain

The character of the terrain or topography in which a highway exists affects the longitudinal and cross section characteristics of the road. The design should be consistent with the terrain. Designers should acknowledge terrain features and limitations in making design decisions. Some of the AASHTO Green Book (1) design criteria are sensitive to terrain. For example, shoulder widths are typically reduced in mountainous terrain. Drivers generally respond to the terrain, operating at higher speeds where the terrain and alignment are flatter and more open.

Note that the actual terrain is a design control over which the design team has no control. However, in some cases, designation of the terrain for a project (which in turn affects the selection of design values) may be a judgment of the designer. Designers can enhance their flexibility within design criteria through careful consideration of the appropriate terrain designation for a given project.

In flat terrain, the horizontal and vertical alignment generally will not be severe. Typical design speeds are higher, and design controls for grade are more restrictive. In rolling to mountainous terrain, the topography produces increasingly greater demands on the designer, who should respond accordingly. Lower design speeds are often used in more difficult terrain; design criteria allow for the use of steeper grades and narrower cross section values in such terrain.

1.4.3 Location

The location of the highway influences driver perceptions, general speeds, and the design approach. The AASHTO Green Book (1) contains separate design criteria for roads in rural areas and urban areas. Urban areas typically have more constraints and the impacts are more severe. For example, right-of-way is typically much more expensive or simply unattainable in urban areas.

Driver expectations and behavior differ in urban areas versus rural areas. Volumes are generally higher and traffic denser in urban areas; drivers are more concerned with pedestrians, bicyclists, parked vehicles, etc. A greater proportion of the traffic stream represents familiar drivers. Conversely, in rural areas there may be a greater number of infrequent or unfamiliar drivers, but fewer pedestrians and cyclists. Note that speeds are generally higher on rural roads, although many urban freeways and major arterial highways operate at high speeds throughout the day.

1.4.4 Traffic Volume

Traffic—volume and composition—is among the most important design controls. The greater the volume of traffic using the facility, the more important are its operational and safety characteristics. Research has confirmed that the single greatest contributor to the risk of a crash is traffic volume. Thus, the amount of traffic for which a highway is designed will be a primary factor in decisions on design exceptions or atypical design approaches.

A highway facility is designed not just for current traffic, but also expected or projected traffic over the life of the highway (20 years hence or longer). The volume of traffic at any point in time will

vary significantly. Normal design practice calls for a *design hourly volume* (DHV) to be established, upon which the operational and geometric characteristics are based.

Designers should recognize that forecast traffic represents, at best, an estimate of what might occur on the road over a long period of time. A traffic forecast represents a technical analysis and policy consensus on the type and developed intensity of land use, the state of the highway network, future regional economic activity, presence of transit service, the needs of pedestrians and cyclists, and many other factors, all of which can vary or change significantly over time.

Design-year forecasts should not be viewed as certain or precise; context-sensitive design recognizes the inherent limitations and uncertainties of such forecasts.

Designers have some latitude in determining what levels of traffic may be appropriate for design. Most travel demand models predict a daily volume; translating average daily traffic (ADT) forecast to DHVs requires additional data and some judgment.

Figure 1-3 shows a typical cumulative plot of traffic volumes on an hourly basis, showing the highest hourly volume of a given year through lesser hourly demands. A designer may choose to design for the 30th or 50th highest hourly volume, which is a common approach for rural areas; or, as is common in suburban and urban areas, the 100th or even 200th highest hourly volume.

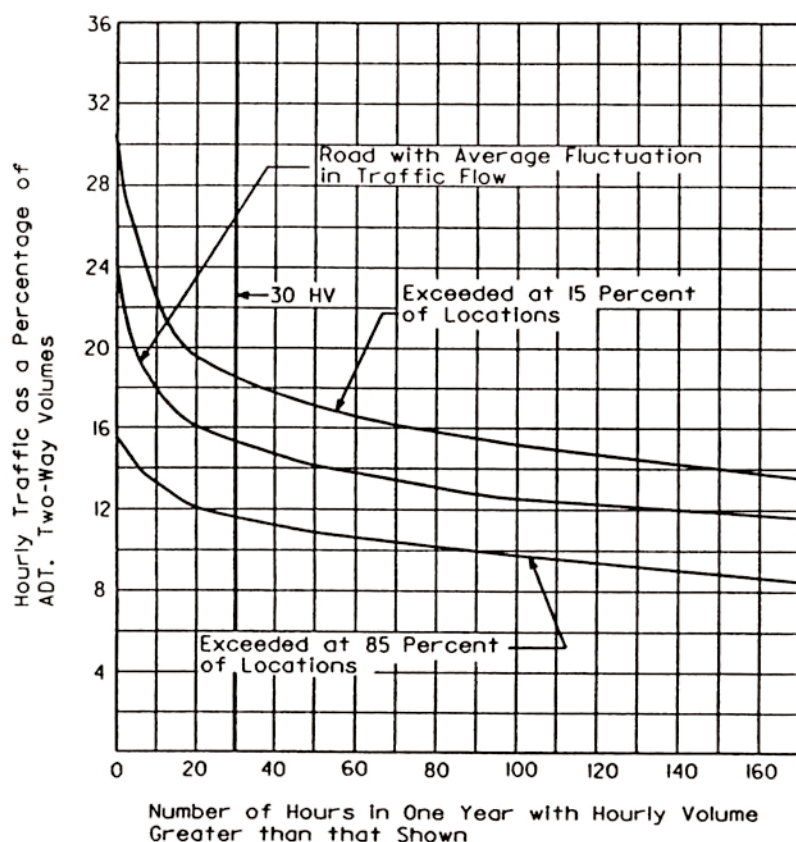


FIGURE 1-3
Alternative Design Hour
Volume Curves

Accommodating a higher hourly volume may mean committing to a larger and more costly facility, and one with potentially greater adverse impacts. Judicious selection of a lower hourly volume (say, 100th versus 50th) may mean that a few more hours during the year will not be

accommodated by the design at the intended level of service, but that the overall design will be sufficient during most of the year.

Designers should recognize that the selection of a DHV is an engineering decision that is independent of the other constraints and controls. Accompanying the determination of design hour traffic is the level of service to which the facility will be designed. The selected design level of service should reflect the project's purpose and need.

1.4.5 Level of Service

Part of the design process involves the selection of the *level of service* the facility should accommodate. Level of service is defined as a qualitative measure describing the operational conditions within a traffic stream and their perception by motorists and/or passengers and other transportation users. Conditions such as speed, travel time, freedom to maneuver, traffic interruptions, and comfort and convenience are used to describe levels of service.

Measures of level of service differ for each different highway type and element. Levels of service are characterized as A (free flow, little delay) through F, (breakdown, forced flow, representative of conditions where arriving traffic exceeds the capacity of the highway or highway feature), with level of service E representative of operation at capacity. The definition of level of service varies with the type of highway (two-lane rural, multilane arterial, freeway) and the highway segment in question (signalized intersection, ramp terminal, weaving section.) The reader is referred to the *Highway Capacity Manual* (TRB Special Report 209) (4) for details and background on technical procedures for determining level of service for the range of highway types.

The selected, specified level of service to be provided for the design hour traffic is a primary design control. Design levels of service traditionally relate to expectations of the public in the areas where the facility is located. Higher levels of service are generally expected in rural and less densely populated areas. In larger cities and developed suburban areas, the public expects or tolerates more congestion and lower levels of service.

The AASHTO Green Book (1) and many agencies provide general guidelines on design levels of service for different conditions. See Table 1-2 for recommended AASHTO levels of service. *Note, however, that these are for guidance only.* Failure to achieve a level of service indicated by Table 1-2 does not constitute a *non-standard* design decision. Indeed, it is common practice in major metropolitan areas to routinely design for certain levels of congestion (level of service D or E), recognizing the impracticality of constructing a highway or highway network to accommodate all potential future vehicle demand. Indeed, the AASHTO Green Book (1) includes discussion of the implications of and recommendations for designing for congestion, thus implying recognition of the practical problems associated with always providing a certain minimum level of service.

Selection of a design level of service represents an important design control that is a choice of the project team. This choice should be made carefully, with the input and understanding of the community and all stakeholders, and with reference to the project's purpose and need. In some cases, environmental regulatory requirements may affect this choice (e.g., for projects or locations in which demonstrated improvements to air quality are necessary). A flexible or context-sensitive approach for a project acknowledges the need to tailor the level of service to other design controls and constraints within the context of the project's purpose and need.

TABLE 1-2

Guide for Selection of Design Levels of Service

Highway Type	Type of Area and Recommended Level of Service			
	Rural Level	Rural Rolling	Rural Mountainous	Urban and Suburban
Freeway	B	B	C	C
Arterial	B	B	C	C
Collector	C	C	D	D
Local	D	D	D	D

Note: General operating conditions for levels of service

A—Free flow, with low volumes and high speeds.

B—Reasonably free flow, but speeds beginning to be restricted by traffic conditions.

C—In stable flow zone, but most drivers restricted in freedom to select their own speed.

D—Approaching unstable flow, drivers have little freedom to maneuver.

E—Unstable flow, may be short stoppages.

Source of table: Exhibit 2-32 in the AASHTO Green Book (1)

Source of notes: *Highway Capacity Manual* (4)

1.4.6 Design Driver and Vehicle

Highway design is generally based on the assumption that drivers are competent and capable. However, certain design criteria are based on relatively conservative assumptions regarding the capabilities of drivers to perceive and react to stimuli. Thus, design values for, as an example, braking at a sight restriction, are based on human factors and a capability that the vast majority of drivers exceed. This is necessary to accommodate the demands of a fatigued, inexperienced, or older driver who may be slower to react than most. The physical and operational characteristics of the design vehicle also influence certain aspects of the highway. Acceleration and deceleration capabilities, speeds achieved on upgrades, swept-path dimensions of turning vehicles, and height of the driver's eye are all design vehicle dimensions of interest.

AASHTO defines a range of *design vehicles* and their characteristics. There is no mandated use of any particular design vehicle for a project. The selection of an appropriate design vehicle should be made carefully with knowledge of the tradeoffs involved (especially with respect to the safety and overall operation of the facility) and input from the public. Designers should select an appropriate design vehicle that represents a cost- and space-effective choice for that project and location. As Figure 1-4 illustrates, for example, a transit bus may represent a reasonable design vehicle, given that the intersection is part of a regular bus route. Selection of a larger semi-trailer as a design vehicle may result in unacceptable impacts to sidewalks and neighboring properties.



FIGURE 1-4
Transit Bus May
Be Appropriate
Design Vehicle
for Urban
Intersection
Design

1.5 Speed—A Fundamental Input to Design

Speed is among the fundamental inputs to design. The design of most of the elements of the highway is predicated first on the establishment of an assumed speed. The concept of *design speed* evolved and was eventually adopted by most AASHTO members by the early 1960s.

AASHTO has recently adopted a new definition of design speed:

Design speed is a selected speed used to determine the various geometric features of the roadway. The assumed design speed should be a logical one with respect to the topography, anticipated operating speed, the adjacent land use, and the functional classification of the highway.

Traditional practice is to provide as high a design speed as is practical. This approach is consistent with the underlying premise that drivers wish to minimize their travel time and delay, and hence desire to travel at as high a speed as they feel comfortable and safe. Indeed, many designers consider design speed as a surrogate for design quality, with use of higher design speeds being considered the best or safest possible approach.

In the context-sensitive environment, particularly in urban areas, great care is suggested in selecting a speed that is reflective of local conditions and driver expectations, and which will not result in substantial problems or costs during execution of the design.

1.5.1 Selecting a Design Speed

The AASHTO Green Book (1) recommends that the selected design speed should accommodate a high percentile of drivers, including the reasonable and prudent driver. It is also important that design speed be consistent with driver expectations. Typically, the higher the functional classification, the higher the design speed.

The AASHTO Green Book (1) provides recommended ranges of values; however, it also states that where significant constraints are encountered, other appropriate values may be employed. Note that a relatively wide range of design speeds may be appropriate for a given highway type, location, and topography, as indicated in Table 1-3. The provision of a range in design speeds, combined with general guidance on selection of a design speed as noted above, represents perhaps the greatest flexibility afforded the designer by the AASHTO Green Book (1). It is the intent of AASHTO that designers exercise judgment in the selection of an appropriate design speed for the particular circumstances and conditions.

TABLE 1-3
AASHTO Recommended Ranges in Design Speeds

Type of Area and Appropriate Design Speed—mph (km/h)				
Highway Type	Rural Level	Rural Rolling	Rural Mountainous	Urban and Suburban
Freeway	70 (110)	70 (110)	50–60 (80–100)	50–70 (80–110)
Arterial	60–75 (100–120)	50–60 (80–100)	40–50 (60–80)	30–60 (50–100)
Collector	40–60 (60–100)	30–50 (50–80)	20–40 (30–60)	30 (50) (or higher)
Local	30–50 (50–80)	20–40 (30–60)	20–30 (30–50)	20–30 (30–50)

Source: AASHTO Green Book (1)

When determining the appropriate design speed—in addition to topography, anticipated land use, and functional classification—the designer should also consider the volumes and composition of the expected vehicular and non-vehicular traffic, the anticipated driver characteristics, and driver familiarity with the route. The designer should consider expected operations throughout the day, including both peak and non-peak hours. Indeed, off-peak traffic flow will generally control the selection of a reasonable design speed. The design speed may vary for any given route as it traverses rural, suburban, and urban areas.

Once these factors have been evaluated and an appropriate design speed determined, the geometric elements should be designed consistently to that level. Where this is not possible for one location or design element, a design exception may be justified.

Current accepted practice is to determine the design speed from observations of the existing or anticipated speed distributions of traffic traveling in fair weather in the off-peak hours. This practice reflects the need to accommodate the speeds of most (but not all) drivers. It also addresses the desirability of meeting the expectations of drivers based on the roadway environment. Numerous studies have indicated that reasonable and prudent drivers, as measured by the 85th percentile speed, will not significantly alter what they consider to be a safe operating speed, regardless of the posted speed limit unless there is constant heavy enforcement. In general, an appropriate design speed should be within approximately 5 mph (10 km/h) of travel speeds.

Higher design speeds impose greater challenges and constraints on designers. Designers faced with difficult or constrained conditions may consider selecting a lower design speed for an element

or portion of the highway. This practice can cause problems in that a large number of drivers may not “behave” as the designer desires or intends them to. Designs based on artificially low operating speeds, instead of the anticipated operating speeds of the reasonable and prudent driver, can result in inappropriate geometric features that violate driver expectations and degrade the safety of the highway. The emphasis should be on the consistency of design so as not to surprise the motorist with unexpected features. Therefore, the design speed should not be based on the speed limit unless the speed limit is based on the anticipated 85th percentile operating speed or is otherwise considered reasonable given expected operating speeds or physical constraints of the built environment.

From the above, AASHTO recommends that designers not propose an alternative design speed for a highway or segment of a project as a design exception. A serious fundamental problem with accepting or allowing a *design exception* for design speed is based on its importance relative to all features of the highway. A reduction in the design speed may be unlikely to affect overall operating speeds. It will potentially result in the unnecessary reduction of all of the speed-related design criteria rather than just the one or two features that led to the need for the exception. The acceptable alternative approach to a design speed exception is to evaluate each geometric feature individually, addressing exceptions for each feature within the context of the appropriate or desirable design speed.

1.5.2 Design in the Lower Speed Environment

There are many situations in urban areas in which attempting to produce or design for lower speeds is appropriate. A low-speed environment is appropriate for residential streets, locations near schools and parks, and in downtown areas where there is considerable pedestrian traffic.

Given the historic equating of design speed with design quality, the notion of designing a *high-quality*, low-speed road is counter-intuitive to some highway engineers. Yet it is in many cases the appropriate solution to a sensitive neighborhood or other street design problem. The severity of pedestrian crashes, a significant concern in urban areas, is greatly increased as speeds increase. Context-sensitive solutions for the urban environment often involve creating a safe roadway environment in which the driver is encouraged by the roadway’s features and the surrounding area to operate at low speeds.

1.5.3 Design Speed and Traffic Calming

Traffic calming is a growing concept that designers must increasingly consider. The term *traffic-calming* refers to a variety of physical measures to reduce vehicular speeds, primarily in residential neighborhoods. The lowering of operating speeds is often the appropriate solution to addressing safety problems. Such problems typically involve vehicle conflicts with pedestrians, bicyclists, and school children.

The above discussion on design speeds should not be construed as representing opposition to properly planned and designed traffic-calming measures. (Research has shown that measurable reductions in operating speeds are possible for some projects as part of a traffic-calming effort.) A local road or street, and in some instances a state highway that functions as a local road or street, may have an existing operating speed far in excess of the speed limit or the desired operating speed. Consistent with the spirit and intent of the design speed discussion on pages 67–68 of the 2001 AASHTO Green Book (1), it is acceptable and consistent with good engineering practice to develop a design that will lower the anticipated operating speed.

Great care must be exercised to ensure that the proposed design will actually reduce the operating speeds to levels consistent with the safe operating speed for the design. The burden is on the individual designer of a traffic-calming feature to document a reasonable expectation that the proposed measures will reduce the operating speed.

The devices that may be used include geometric alternatives such as the introduction of a series of horizontal curves, signing, traffic-calming devices consistent with the new anticipated operating speed, and any other recognized and accepted technique with a proven track record for reducing speeds and maintaining safety. Once the design is complete, careful monitoring of the performance of the project should be undertaken to assure that speeds have indeed been reduced, and to provide valuable lessons for future traffic-calming projects.

Chapter 3 provides more detail on tools and techniques for traffic calming.

1.6 Project Types

In addition to maintenance activities, which constitute the majority of projects undertaken by a state transportation department, agencies typically construct three types of projects. These include:

- New construction (which may involve a roadway on new alignment or major widening or improvement to an existing facility)
- Reconstruction of existing highways
- Resurfacing, restoration, and rehabilitation (3R) projects

Differences among the three types can affect the outlook and decisions about design alternatives.

1.6.1 New Construction

For new roadways or highways on new alignment, the design process involves the evaluation of multiple possible corridors. A new alignment may be sought to serve newly developing land uses, as a bypass of an existing town, or as part of an integrated development plan. New corridor projects often involve the replacement of an older, lower capacity facility such as a two-lane highway that remains for local use, but where through traffic is relocated to a similar or larger highway on a different alignment.

The design process for new alignment corridors involves the identification of right-of-way within which the new road can be constructed. A *space-conservative* approach in the location process is recommended to select such corridors for a number of reasons. First, there is, by definition, no existing highway and no history of operational or safety problems such as speed observations or crash history upon which to base design decisions. This means, among other things, that the designer has less assurance that a design exception will be operationally acceptable for the specific site conditions. Second, projected travel patterns and forecast design volumes are less certain. Design-year traffic forecasts for new routes can be off by 50 percent or more. Third, designers seeking new rights-of-way have more latitude and more options for selecting alternative

corridors. In these cases, every effort should be made to select and evaluate corridors where design exceptions will not be necessary.

1.6.2 Reconstruction of Existing Highways

For projects involving the reconstruction of an existing highway, greater flexibility in the design approach is often necessary. Constraints are generally much greater, resulting in greater impacts and costs. This is particularly true where an existing highway is being widened, and available right-of-way to accomplish such widening is limited or very expensive. In effect, the designer has only one corridor in which to work, and must arrive at an acceptable solution within that corridor regardless of the nature and severity of constraints.

Major reconstruction implies substantial changes to the three-dimensional features of the highway. Many reconstruction projects involve capacity expansion, such as widening from two lanes to four lanes. As noted previously, the geometry of many older highways does not meet current criteria. Existing corridors are typically constrained, leaving few opportunities to upgrade their alignment. Nonetheless, the design criteria contained in the AASHTO Green Book (1) are intended to apply to reconstruction projects.

Designers considering existing alignments should have a much more complete knowledge base about the existing road, which should be useful in making decisions about design exceptions or special, project-specific design criteria. There should be, for example, a well-documented history of traffic volumes and crashes over recent years, enabling good understanding of the actual safety and operational performance of the road given its current geometric conditions. It should be possible to conduct speed and travel time studies to relate the posted speed and typical or desired design speeds to the actual location. This knowledge base provides greater confidence in assessing and correcting existing problems, determining appropriate design speeds, and assessing design exceptions.

Design criteria for such reconstruction projects may appropriately reflect the unique project-specific conditions. Thus, for example, it may be acceptable to retain existing vertical alignment characteristics, even where these are determined to not meet current, full agency design criteria.

1.6.3 Resurfacing, Restoration, and Rehabilitation (3R) Projects

For non-Interstate projects involving resurfacing, restoration, or rehabilitation, achieving AASHTO Green Book (1) criteria is not required. Such projects by definition do not include substantive changes in the geometric character of the road, but a very important consideration is that they enhance safety. Most agencies utilize special design criteria for 3R projects. Criteria generally reflect an acceptance of existing features regardless of whether they meet current agency criteria for a new highway. Of course, an important consideration in retaining an existing design dimension for 3R projects is the safety and operational performance of the existing road.

The reader is referred to TRB Special Report 214, *Designing Safer Roads: Practices for Resurfacing, Restoration, and Rehabilitation (3)*, which documents design criteria and approaches to the design of such projects. Also, many states have adopted their own 3R guidelines.